

## Unit 17: Electrical Circuits and their Applications

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### Delivery guidance

#### Approaching the unit

Science technicians working in industry, education, health or modern research laboratories must frequently demonstrate a clear understanding of electrical concepts and feel confident in the use of instruments and measuring devices. This unit will give learners the knowledge and skills necessary to undertake essential tasks related to electrical circuits and their components. Learners will not need to have detailed prior knowledge of the subject material. The main emphasis in this unit is on development of practical skills, a logical approach to problem-solving and independence in report writing and research.

Your learners will be expected to plan investigations and carry out practical activities with precision and accuracy in order to improve their understanding of electrical 'flow' in a circuit, the use of measuring devices and the numerous components involved. You will introduce them to new electrical terms, calculations and concepts, and they will gain a clear insight into the applications and practicalities of electrical circuits and machinery in all walks of life, developing both their investigative and research skills.

Your learners will need access to essential electrical equipment and research materials, books and the internet. Excursions to linked organisations such as power stations, industrial complexes and electrical distributors would be of significant value. You can use a wide range of delivery methods for this unit, which could include:

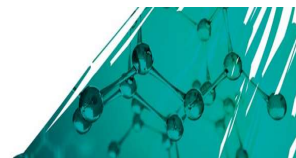
- practical demonstration and investigation – covering the essential requirements of safe working practices, knowledge of circuit components, calculations and measurement techniques
- PowerPoint® presentations – used to introduce the various topics and for your learners to present their work individually or in a group activity
- videos – a wealth of up-to-date presentations are available for you to support formal laboratory teaching with information supplied from industrial establishments
- case studies – these are of value when highlighting the dangers of misuse of electricity and its associated machinery and devices
- discussion – as a means to determine understanding of the subject material by your learners and to inform your way forward in the topics covered

#### Delivering the learning aims

The learning aims covered in this unit are best delivered through a program of formal tuition, practical demonstration, investigation and research.

Your learners will need access to:

- DC electrical circuit boards and the components identified in unit content
- suitable range ammeters, voltmeters, multi-meters and high-impedance analogue or digital (DSO) oscilloscopes – single or dual trace
- a signal generator, microphone and speakers



- standard transformer packs
- 12 V DC power supplies and suitable single cells
- domestic wiring/fuse samples
- rheostats
- electrolysis apparatus
- RCCB and ELCB (for demonstration purposes)
- a variety of sensors for circuit use
- thermocouple components, piezoelectric example model
- data loggers and associated sensors (pH, moisture, light, temperature, pressure)
- a working model for AC transmission (demo) or National STEM Centre e- library video.

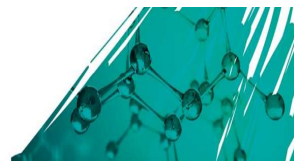
For **learning aims A and B**, your learners will need to understand the main terms, units and relationships used in electrical circuits as listed in the unit content. They could produce a definition catalogue or poster as part of their ongoing learning. It is important to link diagrammatic representation of circuits to correctly set-up demonstration circuits to give evidence and support for electrical quantities and relationships wherever this is appropriate.

Give the learners formulae sheets which incorporate many or all examples of standard suitable calculations that can be performed by the learners and assessed. Ensure that learners have the opportunity to perform unaided calculations of essential electrical quantities using studied relationships. Graphical representations for electrical relationships should be produced as necessary (e.g. resistance, power, charge) and used to explain relationships within the circuit operation.

Practical circuit building and understanding of how and where to measure voltage, current and resistance should be developed by providing opportunities that allow learners to develop competency and confidence with equipment. Learners should develop a clear understanding of the nature of current 'flow' in circuits and be able to present their work in an acceptable investigative form. It is essential to ensure that good combinations of series and parallel circuits are also investigated in order for your learners to gain valuable experience in more realistic circuit designs. Potential divider circuits should also be included. There is some value in a generalised comparison between digital and analogue devices for electrical measurement, but this does not need to be over-emphasised.

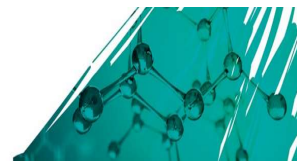
For **learning aims A and B** learners must be assessed in one assignment brief that allows opportunities for learners to demonstrate both their understanding and practical competence.

For **learning aim C**, learners need to be familiar with the basic differences between AC and DC voltage supply. Use the standard internal diagram of a cell to show the passage of electrons, linking this to the DC voltage supplied by a thermocouple and solar cell. For AC voltage, you will need to ensure that learners are familiar with and understand all the principles of Faraday's Law and Lenz's Law, initially by demonstration and then by asking learners to produce practical and reporting evidence. Electromagnetic induction forms the basis of modern-day electrical systems and must be comprehensively addressed in teaching and learning activities. Discuss aspects of step-up and step-down transformers as applied to transmission of AC voltage and explain power loss as heat from electrical cables. Explain RMS values and their DC equivalence, peak voltages and the nature of AC as a sinusoidal waveform. From this, the domestic ring main can be outlined fully in schematic or photographic form, showing the wiring within a standard home setting and the various appliances and terminals. Your learners can be introduced to the variety of methods put in place to reduce risk from mains electricity, such as fuses and circuit breakers, and a further discussion can develop on the equipment seen in practice and to which numerical limits they are



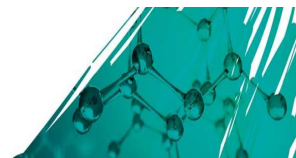
effective. You can then progress to industrial equivalents by showing images or videos of industrial machinery and the safety devices employed. A comparison between domestic and industrial applications can be produced by learners. Introduce a study of the physiological effects of electricity in the body to help further understanding of electric shock, emphasising different effects on the heart of AC and DC. You can also explain that circuit resistance (and body resistance), current and time are the important elements that determine the extent of electric shock.

For **learning aim D**, you should explain transducers in terms of accepted electrical and physical characteristics. Draw attention to their usage rather than energy conversion to help avoid the confusion of 'passive' or 'active' that may arise between some references. In general terms, real transducers (e.g. thermocouple, piezoelectric) produce their own EMF. LDRs, thermistors and strain gauges do not, and should be more properly referred to as electrical sensors. You should give formal guidance on the use of data logging devices and ensure that your learners use data logging devices for physical changes as often as practically possible. They should be familiar with data collection, processing and display. Learners need only to understand their basic function as measurement devices, rather than detailed knowledge of particular functions. You should incorporate suitable practical investigations into both passive and active transducers, allowing learners to determine the relationships involved and to produce valid graphical representation of their results. Emphasise the need for detailed conclusions in their reporting and insist on a range of instruments for measuring and recording. Previous work on the oscilloscope will help in the use of this device for practical display of the conversion of sound into a waveform using a speaker, for example. Learners need to develop competency in constructing simple circuits to demonstrate standard circuit measurement practice using the devices in the unit content. It is essential that learners have direct experience of all these measuring devices in a variety of realistic scientific settings.



## Assessment model

| Learning aim                                                                                                                                           | Key content areas                                                                                                                                                                                                                  | Recommended assessment approach                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A</b> Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits | <b>A1</b> Electrical symbols, units and definitions<br><b>A2</b> Electrical formulae and relationships<br><b>A3</b> Electrical properties and uses of materials                                                                    | Scientific report including use of terms, symbols, units and example calculations.<br>Practical investigation of ohmic/non-ohmic conduction devices.<br>Practical circuit assembly, combination circuits and recorded results.                                                                                                                                                                                             |
| <b>B</b> Construct series and parallel circuits for use in standard electrical applications and measure electrical values                              | <b>B1</b> Circuit characteristics<br><b>B2</b> Measurement devices                                                                                                                                                                 | Records of measurement results of circuit values, resistance values, calculated and predicted comparison.<br>Potential divider circuit work – diagrams and report.                                                                                                                                                                                                                                                         |
| <b>C</b> Examine AC and DC production and health and safety aspects in domestic and industrial applications                                            | <b>C1</b> DC production<br><b>C2</b> AC production and transmission<br><b>C3</b> Domestic applications and mains supply<br><b>C4</b> Industrial applications<br><b>C5</b> Safety, human physiology and electricity and legislation | Report using laboratory and research notes on domestic mains characteristics.<br>Practical investigation into production of induced current/voltage.<br>General study of uses of AC and DC electricity in the home.<br>Case study comparing industrial uses.<br>Report on physiological study of electric shock effects (AC and DC).<br>Industrial site visit to produce site safety report and outline of safety devices. |
| <b>D</b> Examine the uses of transducers, sensors and other measurement devices                                                                        | <b>D1</b> Uses of passive transducers<br><b>D2</b> Uses of active transducers<br><b>D3</b> Uses of sensors and other measuring devices                                                                                             | Circuit construction and report on transducers, sensors and other measurement devices.<br>Report on applications and operation of transducers, sensors and measurement devices.                                                                                                                                                                                                                                            |



## **Assessment guidance**

This unit is internally assessed through three assignments, one covering learning aim A and B, the second covering learning aim C and the third covering learning aim D. Learning aims A and B must be assessed in one assignment brief that allows opportunities for learners to demonstrate both their understanding and practical competence. Learners should produce written evidence, which may be in the form of a report, of their understanding of electrical symbols, units and terms, electrical formulae and relationships, electrical properties and uses of materials, and a practical investigation of characteristics of circuit assemblies that includes examination of predicted and measured quantities. The report must incorporate relevant calculations and allow the use of appropriate graphs.

All learners must independently generate individual evidence that can be authenticated. The main forms of evidence are likely to be written reports, diagrams and investigative articles. There will also be practical observational work including laboratory logbooks, circuit diagrams, schematics and possibly photographic evidence. Learners should incorporate research that is supported by a fully referenced bibliography.

The use of presentations is important and the forms of evidence should include slides, preparation notes, script, cue cards, peer assessment records and an observation record or witness statement where appropriate. The completion of observation records is to be carried out by the assessor and the learner's colleagues in placements or part-time work; other departmental staff and laboratory technicians could complete witness statements. Observation records alone are not sufficient sources of learner evidence; the original learner-generated evidence must also support them. Assessors should remember that they are assessing the content of the presentation against the learning aim and not the skill with which the presentation was delivered.



## Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

### Unit 17: Electrical Circuits and Their Applications

#### Introduction

Outline the learning aims of the unit, the content involved and the expectations for learners in terms of independence and group activities. Begin with a group discussion of the general electrical terms and phrases, determining the extent of learners' knowledge and understanding, and asking them to consider the vast array of applications which electricity has in our lives.

#### Learning aim A: Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits

##### A1

- You should begin with an overview of the principles of electricity, particularly electrical terms and relationships. You should give learners a document that lists all the terms to be used in the unit, together with their definitions, for learners to become familiar with and have access to during their course of study.
- The use of voltmeters and ammeters will be extensive for this unit and learners will need to have access to these and all other electrical circuit devices on a regular basis. Ask learners to link the devices to their appropriate application in electrical circuits by producing a suitable information poster. This poster should not be submitted as evidence.
- Construct and display demonstration circuits prior to delivering information on circuit construction, equipment and calculations. This will help to reinforce understanding of the relationships studied.
- Use appropriate circuit designs on PowerPoint or worksheets to highlight the general characteristics for series and parallel circuits and give learners suitable introductory calculations linking current, voltage and resistance. You will need to explain the fundamentals of current flow in both types of circuit using clear diagrams. You should make sure learners know how to use a suitable calculator so that they can complete the basic calculations to give individual answers.

##### A2

- Introduce the various laws and formulae through formal tuition and example problems, checking that all learners are able to produce detailed notes and follow the appropriate stages in calculations. Many of the terms and relationship formulae will undoubtedly be unfamiliar to learners at first. Learners could create large industrial posters that include all relevant terms, formulae and example calculations in addition to their personal notes.

#### Learning aim A3

- Introduce learners to materials and their uses in electrical circuits with suitable physical examples. This will involve a Q&A session on insulators and conductors, as well as ohmic and non-ohmic conductors. Use graphs to illustrate these. You should ensure that sufficient focus is placed on the characteristics and importance of capacitors in circuits, and demonstrate AC applications. Again, the use of graphs to show charge and discharge is important. Your learners should make valid and accurate notes with example graphs.
- Discuss the uses of semiconductors with your learners, identifying silicon and germanium



as the two main elements. Give basic information on their mode of operation, for example, how their conductivity can be adjusted by mixing with other elements in a circuit, thereby controlling other parts of the circuit. A diode can be used as a graphical example.

- Recap on the general principle of the capacitor in a circuit that has both AC and DC running through it. Explain, in general terms, how the capacitor offers high resistance to DC (e.g. low frequency noise) and low resistance to higher frequency AC signals, thereby acting as a 'filter'. Your learners only need to take suitable notes on this aspect. Demonstrate, by graphical representation and explanation, the exponential charge/discharge for capacitors.
- Assessment will occur when learners have had the opportunity to develop their skills. During assessment, they will use the assignment brief to work independently to produce the required evidence.

### **Learning aim B: Construct series and parallel circuits for use in standard electrical applications and measure electrical values**

#### **B1 & B2**

- With sufficient apparatus and range of resistor values for the group, arrange your learners into pairs. Ask them to construct a working DC circuit using one resistor and then progress to using two and then three resistors in a series circuit. Learners should not be given the opportunity to practice building the same circuits that they will be required to build in the assignment brief. Your learners will need to draw and measure values of voltage and current at suitable points in order to confirm resistance values. Ask them to construct parallel circuits using the same components. Learners should develop skills in producing scientific reports with suitable diagrams and calculations.
- Instruct your learners to assemble a range of independent combination series and parallel circuit types with descriptions using a range of components. Your learners are to complete individual measurement of quantities using digital and analogue devices for later comparison.
- Based on experimental results, ask your learners to give a general summary of their findings comparing calculated values with experimental measurement from circuit work. They should share this with the class and make a collective evaluation. A Q&A session will be useful: Are the values of resistance close to manufacturer values? Why? Is there a significant difference between using analogue to digital devices for measurement?
- Introduce the simple potential divider circuit as a diagram, explaining the general principle. Ask your learners to construct at least two circuits using resistor values that are both equal in one circuit and different in the second circuit. They should confirm the measured values of voltage by calculation and include it in the full circuit report together with suggested applications of the potential divider.
- Explain the nature of measured voltage drop across components in terms of transfer into heat energy and give an opportunity for learners to consider internal resistance in their calculations.
- Assessment will occur when learners have had the opportunity to develop their skills. During assessment, they will use the assignment brief to work independently to produce the evidence indicated in the assignment brief.



### Learning aim C: Examine AC and DC production and health and safety aspects in domestic and industrial applications

#### C1 & C2

- Give an initial introduction to a circus of practical demonstrations which are to be shown. These could include:

- 1 magnetic fields around wire carrying current (using plotting compasses)
- 2 AC production (magnet and coil)
- 3 principle of the simple motor (movement of wire in a magnetic field).

Your learners must take notes with clearly drawn and fully labelled diagrams. You should outline the important rules that apply to your demonstrations, introducing Fleming's right- and left-hand rule, Faraday's Law and Lenz's Law. Learners must include these points in their notes

- Introduce the differences between AC and DC using a demonstration circuit and oscilloscope. You may then wish to discuss the operation of the device in terms of varying the wave amplitude and time base. It is important to ensure that all aspects of the AC wave are reviewed and you can then ask your learners to produce a scientific poster, from demonstration and additional research, which illustrates an accurate set of fully labelled diagrams describing the characteristics of AC and DC waveforms and identifying the differences between them. This poster should not be submitted as evidence.
- Discuss the meaning of root mean square (RMS) values as the AC equivalent of DC current by producing the same heating effect on a resistor. Use the value as 'peak voltage divided by the square root of 2' and state that the AC wave is varying continuously. Explain to learners that it is strictly not the average value of AC since this would obviously be zero. Use the oscilloscope to illustrate the 'peak-to-peak' voltage and how it can be easily found by counting the squares.
- Introduce the principles of the step-up and step-down transformer using a working demonstration. The transformer equation must be given to learners, together with suitable example questions, so that they can quickly identify the simple ratio technique.

#### C3

- Discuss why and how electricity is transmitted on a national scale as AC. You could also share with learners a relevant video based on the national grid format of electricity transmission. Use a working model of power lines and transformers to further illustrate the concepts. Ask learners to identify the advantages of AC transmission over DC transmission in terms of power loss.
- The domestic ring main can be introduced as a general diagram illustrating wiring systems, voltages and current values for specific appliances and fuse ratings. From this, learners can produce a large schematic which can also include notes on the need to use transformers to reduce AC voltages to useable DC voltages and the variety of electrical safety devices used.

#### C4

- Present your learners with an opportunity for two case studies: 'Application of DC electricity for industrial electrolysis' and 'Application of AC electricity in producing a speedometer'. The same case studies should not be used for practice and assessment. Learners need to be supported to understand how to produce case studies. You may wish to include a variation of these topics based on suggestions in the unit content or include your own. Learners will also be expected to give additional comments on the safety devices used in industrial settings, such as line isolation monitoring and isolating transformers.



## C5

- You should give formal tuition on the effects of AC and DC on the human body, typical internal electrical values and conduction characteristics, and the length of exposure time to current. You will also review electrical safety devices – fuses, circuit breakers and earthing systems – and introduce any relevant current legislation. Instruct your learners to produce group presentations with the title 'A Report into Health and Safety when using Electricity'. You will need to outline the topics for inclusion in the reports: biological considerations, operation of a defibrillator, safe levels of DC, etc.

## Learning aim D: Examine the uses of transducers, sensors and other measurement devices

### D1

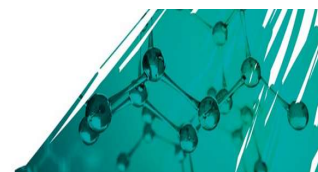
- You can begin this section with a display of both types of transducers: passive and active. Many of these will be in enclosed form so the fundamental 'working' parts may not be easily visible. You can outline the functioning points with a simple schematic of each device set alongside the component. Your learners will then present a document in the form of a 'Guide to transducers and sensors' which illustrates each example with diagrams and its applications.
- Introduce practical investigations for all the sensors listed in the unit content. Your learners could carry out the following practical experiments providing full scientific reports with diagrams, photographs, results and conclusions:
  - pressure sensor – biological blood pressure device
  - pH sensor – calibrating a pH meter
  - moisture sensor
  - temperature sensor
  - LDR – operation of a light dependent resistor in a circuit.

### D2

- Ask your learners to carry out an investigation into the operation of an active transducer – construction and operation of a thermocouple, for example, to measure a given solution and to use a simple calibration method by using a standard thermometer (need for amplification). Your learners should then give details of the mode of operation and comment on improvements to their design if any can be identified.

### D3

- You should introduce a series of activities designed to demonstrate the ability of learners to use a variety of measurement devices effectively and with confidence. This will involve demonstrating some devices and recapping on others already used in the unit. This includes:
  - oscilloscopes to calculate suitable AC voltages (peak-to-peak, root means square, for example) by accounting for vertical scale divisions. Additional use of the oscilloscope to calculate the frequency of the AC signal input using the horizontal scale divisions
  - practical use of ammeter, voltmeter and multi-meter and investigation records during circuit analysis linked to learning aim A
  - practical evidence of the use of data logging for recording and storage of data from a range of sensors (e.g. pressure, pH, temperature). Learners should give displays of information for analysis.



## Details of links to other BTEC units and qualifications and to other relevant units/qualifications

This unit links to:

- *Unit 3: Principles and Applications of Physics I*
- *Unit 4: Investigative Project Skills*
- *Unit 7: Principles and Applications of Physics II*
- *Unit 22: Medical Physics Applications*
- *Unit 23: Materials Science*

## Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Internationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

### Textbooks

Bird, J, *Electrical Circuit Theory and Technology*, 6<sup>th</sup> edition, Routledge, 2017 (ISBN: 9781138673496)

### Videos

You can find a useful range of electrical safety videos on YouTube.

### Websites

Visit the All About Circuits website, this site references online textbooks, video lectures and worksheets on electricity and electronics.

Visit the Electrical Easy website for many useful resources related to electrical circuits and devices.

Visit The Institution of Engineering and Technology website.

Visit the Physics World Online website.

Visit the Health and Safety Executive website for information about health and safety in industry.

*Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors' bookmark useful websites and consider enabling students to access them through the school/college intranet*